POTENTIAL COST SAVINGS THROUGH ADVANCED NDE

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I certainly would like to extend the same welcome that has been extended by other people here on behalf of the Air Force. What I'm going to try to cover today is perhaps some different concepts in looking at the benefits to be obtained from nondestructive evaluation with an emphasis on the maintenance rather than the acquisition side of the picture.

I would like to point out that, although the title of this talk is "Potential Cost Savings Through Advanced NDE," it doesn't mean that we're ignoring the area of structural safety, but rather we're trying to add to it. In addition, we're not ignoring the role of NDE in the utilization of new cost effective materials and structures, but this area has been discussed previously and I believe is fairly well established.

In order to get an estimate of the NDE costs associated with aircraft acquisition, let us examine Table I.

Table I. DOD Aircraft Acquisition Costs

	FY75	($ in millions)	FY76
Army	188.7		300.2
Navy	2062.2		2200.7
Air Force	2978.0		3985.9
	5288.9		6486.8

The total DOD expenditure in FY75 is over 5 billion dollars and over 6 billion dollars planned for FY76.

As shown in Table II, if you take a look at where the costs are for a typical military aircraft, the airframe accounts for about 60 percent, the engines 18 percent, the avionics 19 percent and subsystems approximately 3 percent.

Table II. Relative Aircraft Component Costs

Component	% of Total Cost	%Q.A.
Airframe	60	9.5
Engines	18	4.7
Avionics	19	--
Subsystems	3	--

This breakdown will vary for each particular aircraft but will serve as a reasonable estimate. The percentages of these costs for quality assurance (primarily inspection costs) are also shown. If we multiply the percentage for Q.A. for each component by the percentage of the total cost for each component, we arrive at an estimate of 6.5 percent of the total acquisition cost due to Q.A. For FY75 this equates to over 300 million dollars and in FY76 to over 400 million dollars.

That sounds like a pretty large sum of money until we look at the maintenance area, and I think this is the area where advanced NDE may have the largest impact. The total Air Force budget (or the obligation authority) is approximately $30.2 billion in FY76. For aircraft maintenance, a reasonable estimate is 4.4 billion as well as we can measure it, with 1.1 billion in depot maintenance and 3.3 billion in field maintenance. In terms of personnel, we have an estimated 206,000 out of a total Air Force strength of 851,000 in the maintenance area.

The average cost of flying an airplane also provides some interesting insight. An F-4C costs about $1539.00 an hour to operate. Of this total 63 percent is due to maintenance. So, we're now speaking of a very large amount of money. This is just aircraft in the Air Force. If you extrapolate this percentage over all of DOD it is clear that the total cost of maintenance is very large.

I'd like to explain what is meant by "depot" and base maintenance just to give you an idea of how aircraft maintenance is performed today in the USAF. Program Depot Maintenance (PDM) is scheduled currently on a calendar months basis, usually 24 to 36 months. During this maintenance a major inspection and overhaul, if necessary, of the airplane are accomplished.

At base maintenance we currently pull inspections based on the number of flying hours. As an example, for the F-4, it's done every 75 flight hours. These two schedules are not related. There's also a third level of maintenance, which is the organizational one, however inspection is generally not performed at this level. The time the aircraft spends in the dock for each visit ranges from one to over two days, while a PDM may run up to 90 days. In addition, there is a delay, another loss in the aircraft availability, because of an impending inspection. Before it is going into the dock, the base level inspection, the sorties per day decrease. When it comes back out of it, they are slow in getting back up to the usual rate. Well, what's going on? Before the aircraft goes for inspection and maintenance apparently the attitude is "Well, it's going into maintenance, don't bother with that plane, worry about this one over here." So, you have more failures just before it goes in. It goes into the docks and just like bringing your car in for repair, mistakes are made which cause additional losses in availability to correct those mistakes. So, fewer planes are available. Therefore, although the actual time in inspection is not very large, there is an average loss of 17 days of operational flying per aircraft per year, which is about 11 days over what it would be with just the time in the docks.

I would like to give you a quick idea of what's involved in a PDM. TableIIIis a breakdown of the F-106 PDM manhours for the FY76.

Table III. F-106 Programmed Depot Maintenance Manhours (FY76)

		Manhours
I.	Basic Tasks 68/A/C at 4580 MH Each	311,460
II.	Modifications	181,744
III.	Misc. Requirements	
	Special Inspections	18,500
	Crash Damage Repair 2 A/C	22,000
TOTAL MANHOURS		533,700

As can be seen, a considerable amount of manpower is expended for these 68 aircraft. The basic tasks are primarily performed to inspect the airframe, but a majority of manhours are spent on cleaning, removing parts, repainting, lubricating, etc. They run some special inspections on a few aircraft and anticipate some repair, with the sum of that package being over 500,000 manhours. We have approximately 242 F-106's, a small part of the total Air Force inventory.

I'd like to introduce the concept of effectiveness as a method of tying this altogether. The effectiveness of a fleet of airplanes is a product of the force coefficient F, which is the percentage of time that it is not in the depot (since it is not available while it's in the depot) times the availability coefficient, which is the ratio of successful to attempted sorties. If you take the total number of airplanes you have times the effectiveness of that particular aircraft, you end up with a figure for what we'll call the net force, which is the number of aircraft that should be able to complete a sortie in a given fleet of aircraft.

As an example of what this will mean, the PDM cycle for the F-106 fleet has been extended from 24 to 36 months. With a 24 month PDM cycle the effectiveness was .695, therefore the net force was 168 aircraft. This means that on the average you could expect 168 planes at any given time to successfully complete the mission. When they went to a 36 month PDM cycle, their effectiveness increased to .72 which resulted in an increase in the net force of 6 aircraft.

It is interesting to note the change in effectiveness as a function of the PDM interval. For all cases with which I am familiar the effectiveness increases as the interval is extended. Some other interesting things happen as the interval is extended. For the F-106 the availability coefficient, which is the time it is not in field maintenance, decreased slightly as the PDM interval was extended. In addition, the dependability coefficient increased signigicantly (the ratio of successful to attempted sorties) and the field manhours decreased signigicantly. Now, this was due to changes in the depot inspection interval, not the base interval. It seems to say that the field spent less time correcting what the depot had done.

Finally, it is interesting to note that in addition to increasing the effectiveness, the total maintenance costs decreased. This looks almost too good to be true. What we've done is stretch out the interval, and have more planes available, for less money. So, the basic point I would like to make is that we should seriously examine opportunities to extend the maintenance interval.

Rand has been conducting a logistics program for the Air Force for several years and a great deal of what I have been covering is based on my interpretation of their analysis of this area. As Rand has noted, today there are no analytical solutions to arrive at the optimum inspection interval, therefore we presently have policy answers for engineering questions.

Well, what can NDE do in this area? Where does it all fit it? As an example let's just assume that the PDM cycle for the F-106 could be doubled. And if we also assume then that the behavior is linear still, we just extrapolate a plot of effectiveness versus PDM cycle, from 36 to 72 months. In this case the effectiveness would go from .72 to .94. This would result in an increase in the net force of 52 aircraft. That would mean that you could obviously increase your net force. Or, you could reduce the fleet and achieve the same capability with 57 less aircraft - a concurrent savings in operating and maintenance costs of 35 million a year.

Overall, the potential impact of extending the maintenance interval is very significant. And it even gets into some interesting arguments that it would provide an option to reduce the acquisition budget. Simply, the argument goes, an increased effectiveness of only 10 percent, for example, on the F-16 would allow you the option of buying approximately 10 percent fewer aircraft. So, you would save the cost of, say 65 aircraft, and you would also save their operating and maintenance costs. Therefore, there is a potential savings on one weapons system which might approach a billion dollars. The leverage in this field is fantastic. Now, there may be many reasons why you probably wouldn't choose to buy fewer aircraft, but it is an option which you would have which you didn't before.

Well, NDE will not provide us with this impact by itself, at least not as we speak of it today. It is a key ingredient that is a necessary but not sufficient condition. The modes of failure as well as the environment are equally important in optimizing the realiability of systems. If we want to extend the maintenance interval, how does NDE contribute? Well, based on a simple fracture mechanics model and equating cycles to failure to the inspection interval, it is clear that if we can detect smaller defects, we can extend the inspection interval.

Well, that seems to say, "Ah, that's the answer." But the answer isn't just to increase sensitivity, because in many cases what we measure is a very poor measure of defect size. In fact, to try to talk of the size of defects today is putting yourself on very shaky grounds. We don't presently have a truly quantitative NDE capability. We have to develop a quantitative ability before we try to look for smaller defects so that we know what we're measuring. And that really gets us back to this program at the Science Center. It is necessary to have quantitative information to be able to make a decision to condemn the part or not to condemn the part and to set the intervals for inspection.

And one last comment. Perhaps a lot of you are aware of the recent studies that have been coming out of the National Academy of Sciences in the materials area. NDE in this area had the highest national priority for both basic and applied research, and that was very unusual since this was the only area that had the highest priority for both categories. They interpreted basic research as a measure of the opportunity for understanding or discoveries and applied research as a measure of the need for new understanding or discoveries. So, NDE falls in that unique category where it has both the highest need and the highest opportunity. And I think if you start talking about its impact on systems as a whole, particularly, in the maintenance area, it has the opportunity to really revolutionize how we do maintenance.